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AN EVALUATION OF CANAL MORPHOLOGY AT DIFFERENT LEVELS OF ROOT RESECTION IN MANDIBULAR INCISORS

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Apical Canal Anatomy

Abstract

One hundred randomly selected mandibular incisors were examined to assess the prevalence and location of two canals and to describe the canal anatomy that may be encountered during apical surgery. The roots were resected at 1, 2, and 3mm apical sections simulating a 20-degree beveled surgical resection. The sections were digitally imaged at X50 magnification and canal dimensions were measured using imaging software.

The prevalence of two canals was 2% at 1mm, 0% at 2mm and 1% at 3mm. At these levels in the roots, the canal was rarely separated by hard tooth structure. An isthmus of tissue was present 20% of the time at 1mm, 30% at 2mm and 55% at 3mm. Four distinct canal types were noted: (1) round, (2) oval, (3) long oval and (4) ribbon. In 75% of the teeth, the canal shapes varied from one level to the next. The more coronally the root-end resection was made the more elongated the canal tended to become.

The prevalence of two canals in mandibular incisor teeth has been reported to be from 11.5 to 44.1 %, although many merge into one canal in the apical 1-3mm of the root (1-6). Authors studying roots with two canals commonly report an isthmus, fin or corridor, which may be present between the two canals (7-10). Green described this corridor as a "ribbon-shaped passage" which viewed in transverse section, is a narrow slit. He found this ribbon-shaped passage in 22% of mandibular central and lateral incisors (7). Non-surgical root canal therapy failure has been attributed to an inability to debride this area adequately (11). In some roots with two canals, periapical surgery is required to facilitate cleaning and sealing the root canal system.

Historically, a steep facial bevel has been required during surgical endodontics to visualize the canal space due to the lingual inclination of mandibular incisors. Recently introduced surgical microscopy and ultrasonic root-end preparation allow the clinician to better visualize the apex and resect the root-end more perpendicularly to the long axis of the root. Root-end resection may potentially expose a second canal or an isthmus (12). Greater knowledge of canal anatomy in the apical third of the root will help the clinician in preparing this area and sealing the root canal system. Cambruzzi and Marshall examined the roots of mandibular molars and the mesiobuccal (MB) root of maxillary molars for the presence of an isthmus using a surgical approach study (9). They stressed the importance of incorporating the isthmus into the root-end preparation to ensure complete debridement and sealing of the root canal system. Weller, Niemczyk, and Kim sectioned the MB root of maxillary molars perpendicular to the long axis and reported the incidence and position of the canal isthmus at each level of resection (8).

To date, however, there have been no studies of mandibular incisors examining the canal anatomy using a surgical resection method. Therefore, the purpose of this study was to determine the prevalence of two canals and an isthmus in mandibular incisors at three levels and to describe the canal anatomy in a simulated 20-degree surgical resection.

Materials and Methods

One hundred human mandibular incisors were randomly collected and stored in 10% formalin. No attempt was made to differentiate between central and lateral incisors. The age, sex, and race of the patients were unknown. The teeth were placed in 5.25% NaOCl (Clorox; Clorox Co., Oakland, CA) for 15 minutes after which any remaining external tissue or debris was removed by scaling. The teeth were radiographed from clinical and proximal views using intraoral Kodak Ultraspeed, size 2, Super poly-soft packet, dental x-ray film (Eastman Kodak Co; Rochester, NY). These films were exposed for 0.27 seconds with a dental X-ray unit (Intrex; SS White) at 70 kVp and 10 mA with a 16-inch source-object distance. All films were uniformly developed in an automatic processor (A/T 2000; Air

Techniques, Inc, Hicksville, NY). The teeth were then embedded in clear casting resin (ETI, Fields Landing, CA). Apices of the mandibular incisors were resected at a 20-degree facial bevel. The lingual edge of the cut was placed at 1, 2, and 3mm from the anatomical apex using a low-speed saw (Isomet; Buehler Ltd., Lake Bluff, IL). Sections were marked so facial, lingual, coronal and apical sides could be identified. These sections were placed in 5.25% NaOCl for 45 minutes to remove any organic material remaining in the canal space. Sections were then placed on a light field stage and imaged with a high resolution CCD camera (TM-840; Pulnix America, Inc., Sunnyvale, CA) at X50 magnification. Image measurements were made on a personal computer (P5-90; Gateway 2000, Sioux City, SD) using software developed at the University of Texas Health Science Center at San Antonio (UT ImageTool for Windows, version 1.21). The presence of an isthmus, number, shape, area, and dimensions of the canal at each level of resection were recorded.

Results

Number of Canals

Two separate canals were found 2% of the time at 1mm, 0% at 2mm, and 1% at 3mm from the apex. At these levels in the root, almost all the teeth had one canal.

Presence of an Isthmus

An isthmus was present in 20% of the teeth at the 1mm level, 30% at 2mm and 55% at 3mm.

Canal Shape

Canal shapes were classified into four distinct types: (1) round (2) oval (3) long oval and (4) ribbon shaped (Figure 1). The shape of the canal is shown at each resection level (Table 1). In 75% of the teeth, the canal shape did not remain constant from one level to the next. Generally, the canals were more round or oval closer to the apex and tended to elongate to a long oval or ribbon shape more coronally.

Canal Area

Table 2 shows the area measurements of the canal at each level. In 18% of the canals, the canal area was greater in the apical section than in the coronal section. On average, there is a 33.3% increase in area when resecting from the 1mm to the 2mm level, a 29.4% increase in area from 2mm to the 3mm, making a total area increase of 88.8% when resecting from 1mm to 3mm.

Canal Dimensions

The mesiodistal measurement of the canal at each resection level is displayed in Table 3. This was generally the narrowest dimension of the canal. Table 4 shows the faciolingual measurement of the canal at each resection level. The data reveal that the faciolingual canal dimensions generally decreased more apically in the root. Of the 300 sections measured, only two sections had a larger mesiodistal canal dimension when compared to its faciolingual canal dimension. These both occurred in the 1-mm section.

Discussion

Successful endodontic therapy depends on the practitioner's ability to find, clean, shape, and seal the canal system. A thorough understanding of root canal anatomy is necessary if one is to accomplish these tasks. This study used a surgical root-end resection approach to examine the root canal anatomy of mandibular incisors. The findings of this study have implications in both non-surgical and surgical endodontic therapy.

Finding two distinct canals at each level was a rare occurrence. In teeth that radiographically appeared to have two canals, there was an isthmus between the main canals at the resection levels studied. In all but three sections, they were not separated by hard tooth structure and were thus counted as one canal in our study. Benjamin and Dowson reported that mandibular incisors have two canals 41.4% of the time (3). This differs from the results of the present study. A possible explanation for this difference is that Benjamin and Dowson placed endodontic files in the canals, then radiographed the teeth. They did not attempt to determine whether a wall of dentin separated two distinct canals or whether the two canals were actually connected by an isthmus of pulp tissue. Green explained that a corridor-shaped canal tended to appear as two separate canals on the radiograph (7). This study demonstrates that, at the apical 1, 2, 3-mm levels in the root, the canal is rarely separated by hard tooth structure and that an isthmus of tissue is frequently present. Thus standard instrumentation techniques may not adequately prepare canals with an isthmus. These findings support the idea that other methods, in addition to mechanical instrumentation, should be used to clean the connection between instrumented portions of the canal during non-surgical endodontic treatment. This could include the use of calcium hydroxide, NaOCl irrigation, and/or ultrasonics (13-15). Additionally, when two canals are obturated and apical surgery is performed it is important to know that the isthmus must be included in the apical preparation. A class 1 root-end preparation connecting the canals and a root-end filling is recommended to seal the connection. Under magnification, the connection between main canals was easily observed because of the broad nature of the isthmus. Weller, Niemczyk, and Kim found that the connection between main canals in the MB roots of maxillary molars was thin and might be missed; therefore the presence of an isthmus must be assumed in those teeth (8).

Two percent of the teeth had two canals at the 1mm-resection level. This study did not determine if these canals remained separate to the apex of the tooth. However, if they did, it would be consistent with the 1 to 5.5% of mandibular incisors with two main apical foramina found in other studies (2, 3, 6, 16, 17).

The canals were classified into 4 broad categories of round, oval, long oval, and ribbon shapes. The long oval and ribbon shaped canals were those that could be characterized as having an isthmus in teeth instrumented as two canals. It was interesting to note that the canal shape did not always remain constant. It generally was more ribbon or long oval shaped in the 3mm sections and became round or oval in the 1mm sections. This is consistent with the idea that two canals merge to exit through one foramen in most cases. The high success rate of non-surgical root canal therapy may be, in part, related to sealing the apical foramen and entombing debris in the isthmus areas. However in surgical endodontics, an undebrided isthmus is more likely to be exposed the more coronally the root-end is resected.

Interestingly, in 18% of the teeth, the apical area of the root canal was larger than the more coronal area. Cleaning the apical portions of these canals could be more difficult during non-surgical endodontic treatment.

The width measurement results show that on average a #25 file is needed to cut dentin in the mesiodistal dimension at 1mm from the apex. However, in the extreme case, a #40 file would initially be needed to bind in the smaller mesial-distal direction at 1mm. This information suggests that final apical preparation size in non-surgical root canal therapy should be larger than a #35 file to adequately debride most mandibular incisors.

Instrumenting the larger faciolingual dimension of the canal in these teeth may be impossible with pure rotary motions, because of the narrower mesiodistal width of the root. In most mandibular incisors, a lateral perforation could occur before the complete isthmus is totally instrumented.

The faciolingual measurements are somewhat longer than a perpendicular resection would have produced due to the 20-degree beveled resection. The 20-degree bevel was made to simulate the type of bevel made during the surgical treatment of these teeth using a microscope. The faciolingual dimension of the canal is on average over twice the length of the mesiodistal.

This study showed that 98-100% of mandibular incisors have one canal in the area 1 to 3 mm from the apex. It was shown that the more coronally the root-end resection was made the more elongated the canal tended to become. An isthmus opened during surgery needs to be included in the root-end preparation. The findings are also significant for non-surgical endodontics, showing that when an isthmus is present it may be impossible to adequately debride with purely rotary techniques because of the longer faciolingual dimension of the canal.

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TABLE 1- Canal Shapes

	1mm	2mm	3mm	Total
Round	22	12	3	37
Oval	58	58	42	158
Long Oval	9	21	40	70
Ribbon	11	9	15	35
Total	100	100	100	300

TABLE 2- Canal Area in mm^2

	1mm	2mm	3mm
Average Area	0.09	0.12	0.17
Range	0.04-0.23	0.05-0.34	0.05-0.39
Mode	0.08	0.08	0.16
Median	0.09	0.11	0.16

TABLE 3- Mesiodistal Canal Measurements in mm

	1mm	2mm	3mm
Average Width	0.23	0.23	0.26
Range	0.13-0.4	0.12-0.48	0.15-0.51
Mode	0.22	0.22	0.17
Median	0.22	0.22	0.25

TABLE 4- Faciolingual Canal Measurements in mm

	1mm	2mm	3mm
Average Length	0.49	0.58	0.75
Range	0.18-1.49	0.22-1.57	0.21-2.19
Mode	0.28	0.66	0.75
Median	0.42	0.53	0.72

Figure

Figure 1-Representative sections showing the different canal shapes. A- round, B-oval, C- long oval, and D- ribbon.